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THE CLIMATE OF THE MIDNINETEENTH CENTURY UNITED STATES COMPARED TO THE CURRENT NORMALS

E. W. WAHL and T. L. LAWSON

Department of Meteorology, The University of Wisconsin, Madison, Wis.

ABSTRACT

Climatic data for the Continental United States for the 1850's and 1860's are compared with the currently valid normals. In the eastern half of the United States, these two decades continue the cooler and somewhat wetter character found in an earlier investigation, while in the western half, a distinctly warmer and decisively wetter climate existed in the mid-19th century, as compared to the conditions in the first half of the 20th century.

1. INTRODUCTION

In an earlier study (Wahl 1968), the early climatological data for the eastern United States pertaining to the two decades from about 1830 through 1849 were investigated. Both by statistical treatment of these early data and by other indirect evidence, it was established that these decades were decisively cooler and, in some regions, somewhat wetter than the climatic normals based on the 30 yr, 1931–1960. The latter is more representative of the peak of the warming trend in the first half of our century.

The availability of such records, before 1850, was essentially limited to the Eastern States. With the settlement of the western States and the sudden opening of the Far West, due to the "Gold Rush" in the late 1840's, the data coverage in those areas began to increase rapidly. In the two decades from 1850 to 1869, a sufficient number of stations were established to allow a climatic analysis of the whole of the Continental United States for the first time (for example, Blodget 1857).

2. DATA AND THEIR TREATMENT

Our procedure for dealing with the available data was essentially as described in the earlier paper (Wahl 1968); in fact, the source of data for these two decades was the same (Schott 1876, 1881). Again, individual station records were combined to form area averages, weighted according to length of record, and finally combined into seasonal averages, employing the same five seasons: winter (January through March), spring (April through June), summer (July, August), early fall (September, October), and late fall (November, December). These appeared to give the best subdivision of the annual variations. It was not possible in all cases to employ exactly the same area boundaries which had been used before; however, the results seem to indicate that those changes which had to be made did not materially alter the overall patterns and their internal consistency. A total of 35 areas were used to cover the United States, with at least two individual stations contained in an area. Most of them, however, contain far more station records than this minimum. As before, the amount of data for investigation of the precipitation was less than that available for the temperature departures; consequently, the results pertaining to the wet/dry contrast are somewhat less definite.

After having established, in the previous paper, the consistency of the instrumental data from these early periods by comparison with other independent evidence, we made no additional attempt to follow these lines. The results presented below were obtained exclusively from the records of temperature and precipitation amounts at available stations during the two decades 1850–1869. Initially, we analyzed separately the two periods 1850/9 and 1860/9. However, the resulting patterns, taking into consideration the internal variability of the data and our intent to derive large-scale anomaly patterns, were so much alike in all cases that composite maps (figs. 1–12) for the total time period 1850 through 1869 were compiled.

3. RESULTS

The intent of this study was to examine the large-scale anomaly patterns and their general features. When one compares the patterns (especially on the temperature anomaly maps, figs. 1–6) obtained for the 1850–69 period for the eastern United States with those obtained earlier

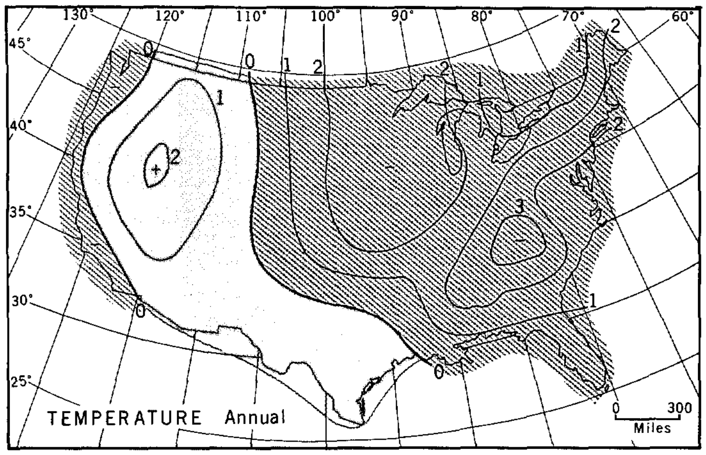

FIGURE 1.—Temperature deviations (°F) of the data in the 1850's and 1860's from climatic normals 1931–1960; annual average.

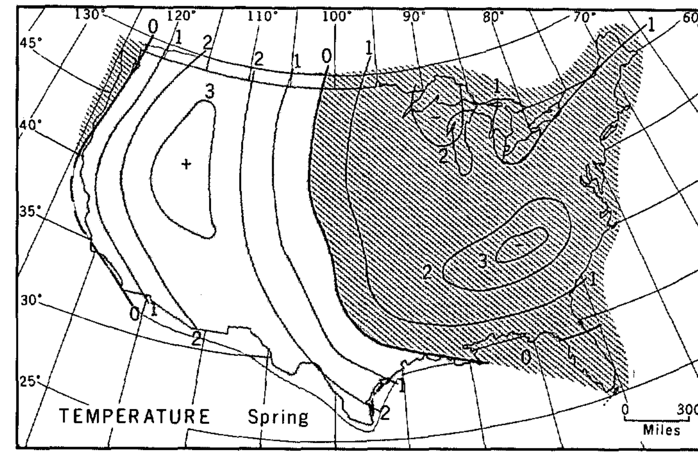

FIGURE 3.—Same as figure 1; spring (April through June).

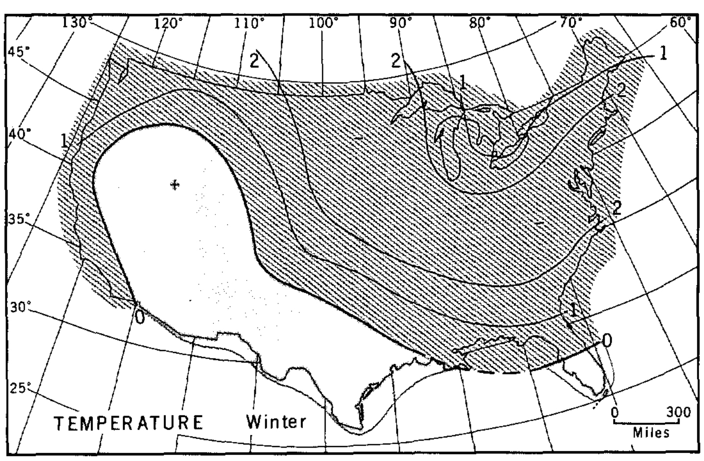

FIGURE 2.—Same as figure 1; winter (January through March).

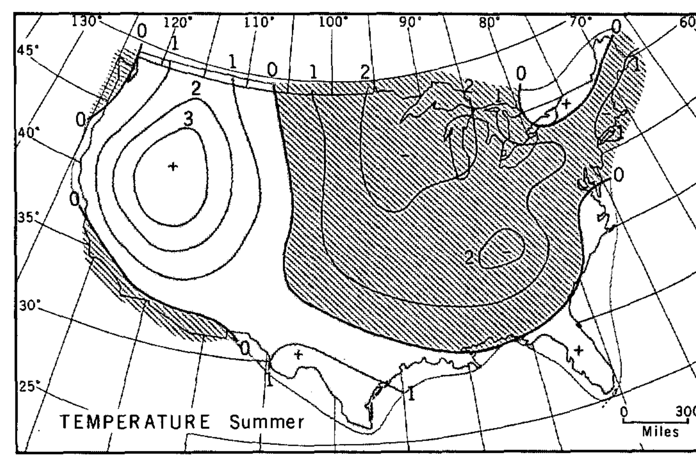

FIGURE 4.—Same as figure 1; summer (July through August).

for the 1830's, one is struck by the close similarity of the results which extends even to rather minor details. As before, a decisively cooler climate is evident, with the largest negative departures occurring during the early fall season. The rainfall patterns (figs. 7–12) are somewhat more varied and do not quite match; however, even in the 1830's, these departures rarely exceeded 20 percent and, on an annual basis, were so small that, in the earlier paper, this particular map was not even included. The annual precipitation departure field in the 1850's in the eastern United States obviously indicates a similar structure.

The second striking result, common to practically all maps for the 1850's, is the distinct contrast between East and West. In the temperature field, a consistent positive anomaly exists over the Mountain States and especially the Great Basin, while in the precipitation, a large area of above-normal departures is evident in roughly the same area. These patterns are quite consistent throughout the whole year; only the intensity and geographic location shift slightly between the seasons. Even the coastal regions on the Pacific behave consistently, being slightly cooler and drier during these decades than in the mid-20th century.

One feature of the precipitation patterns especially noticeable in winter (fig. 8) is the rather unexpected eastward extension of the positive anomaly patterns into the Northern Plains States. In fact, the largest percentage departures on the winter map occur over North Dakota and Minnesota. However, these large departures actually do not constitute a very significant physical change in the actual amounts of rainfall due to the fact that the normal precipitation amount itself is rather small. For example, the normal amount in winter for Bismarck, N. Dak., is only 0.61 in./mo, with a standard deviation of 0.30 in. Applying the usual t-test to these figures and solving for the required difference in inches between a 20-yr average (early period) and a 30-yr average (normal period) to be statistically significant at the 5, 1, and 0.1 percent levels, one finds values of 29, 39, and 51 percent, respectively. Thus, even the largest departures from normal observed in these regions barely exceed the 1 to 5 percent level. Meteorologically, this also appears to be

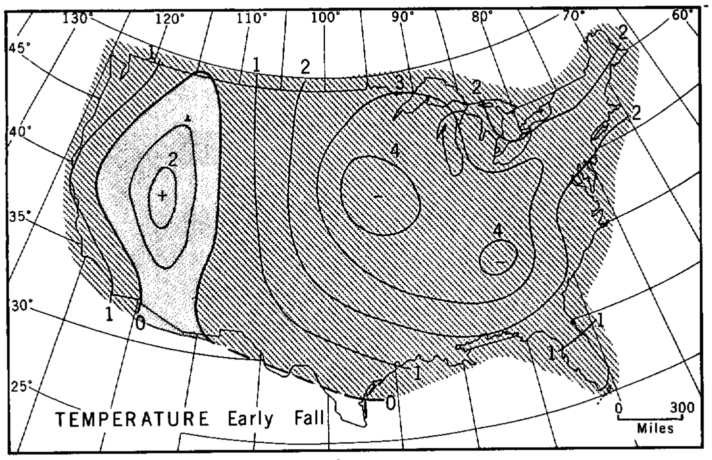

FIGURE 5.—Same as figure 1; early fall (September through October).

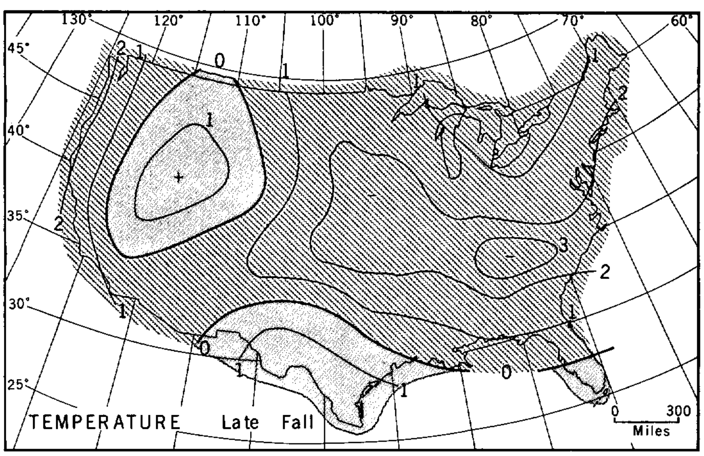

FIGURE 6.—Same as figure 1; late fall (November through December).

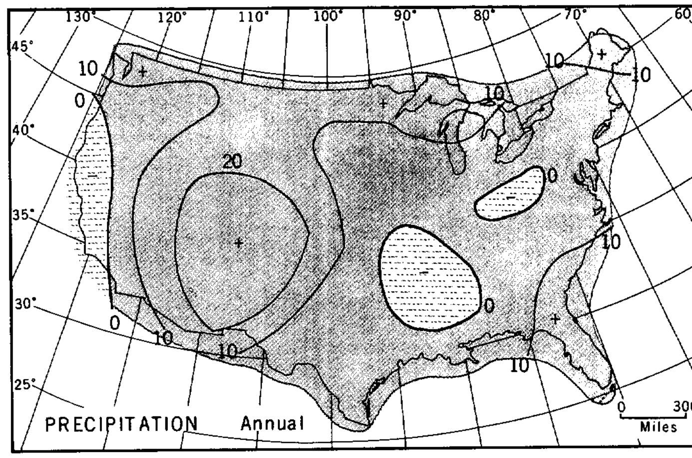

FIGURE 7.—Precipitation departures of the data in the 1850's and 1860's from climatic normals 1931–1960 (in percent of normal amount); annual averages.

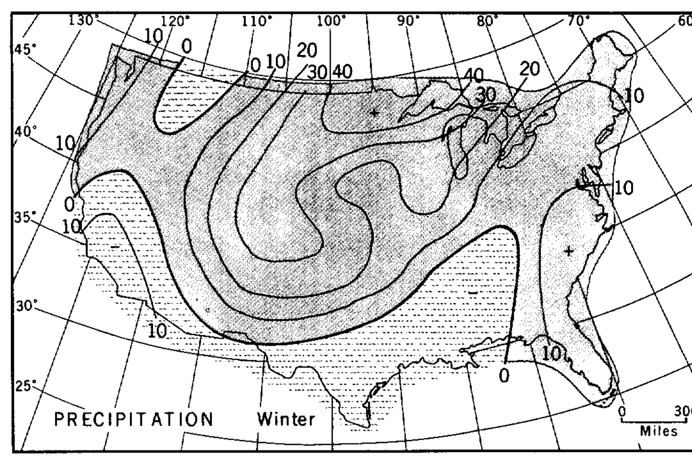

FIGURE 8.—Same as figure 7; winter (January through March).

quite reasonable; just one or two chance occurrences in a particular year of one snowstorm could easily alter one or the other "average" by, say, 0.2 in., a value which is all that is required to result in a better than 30 percent positive departure.

This clearly points up the fact that one has to interpret the precipitation departure maps carefully, especially in regions with small absolute rainfall totals. Fortunately, most regions and seasons have considerably more total precipitation, so that the percentage departures are indeed a reasonable measure of climatic change in this element.

The results in the earlier paper (Wahl 1968) and those reported here essentially cover the period from somewhere around 1830 to approximately 1869. It is somewhat problematic to say something about the next decade, during which the establishment of a large number of stations by the U.S. Weather Bureau was initiated. Stations were moved or newly organized, and it appears that it often took some time before truly representative values were obtained. We were able, however, to look at some preliminary results that Rosendal (1968) obtained from a scrutiny of climatic data for the decade 1880–1889. His maps of departure from our current normals (by months and seasons) indicate rather clearly that, at least in temperature, the basic character of the patterns (cooler in the East, warmer in the West) still existed in that decade; however, his investigations also appear to show that, in the later years of that decade, a tendency toward a major change was becoming more and more pronounced. In the precipitation maps, the broad patterns are still recognizable, but the overall distribution of values (based on selected first-order stations) already becomes somewhat confused and certainly much less clear-cut than that of our earlier periods. We take his results to mean that the climatic period characterized by the departure patterns of the mid-19th century apparently comes to an end during the 1880's.

4. RELATION TO OTHER EVIDENCE OF CLIMATIC CHANGE

If the results presented here and in the earlier paper in

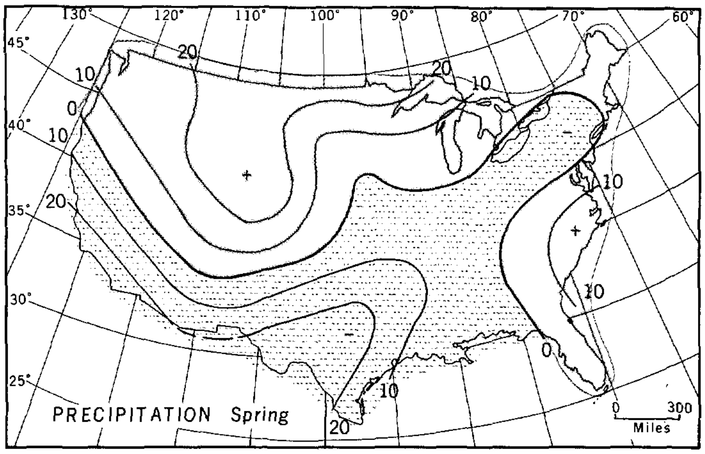

FIGURE 9.—Same as figure 7; spring (April through June).

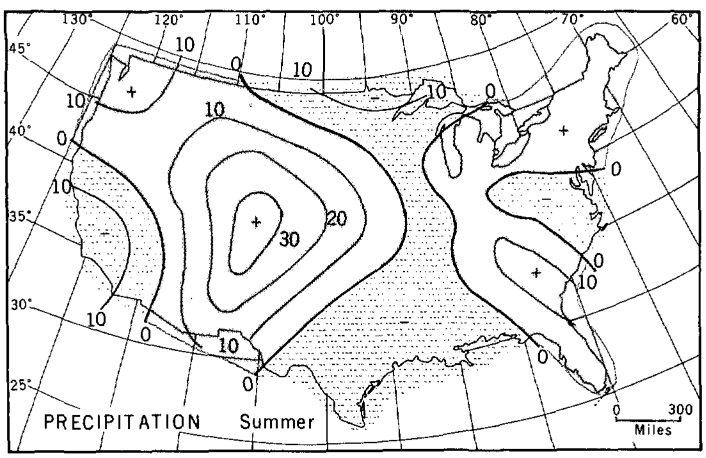

FIGURE 10.—Same as figure 7; summer (July through August).

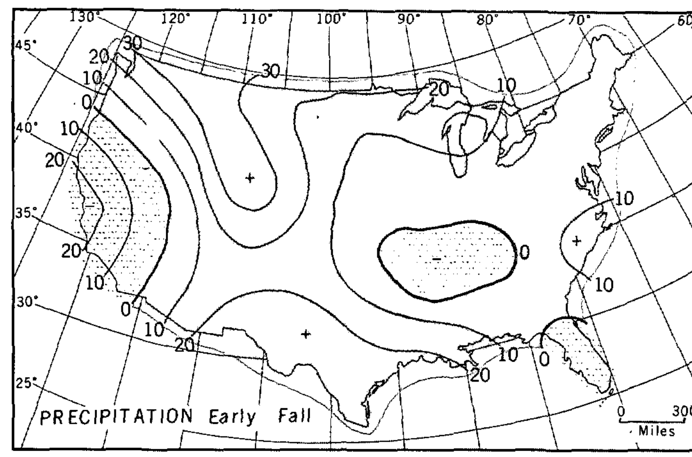

FIGURE 11.—Same as figure 7; early fall (September through October).

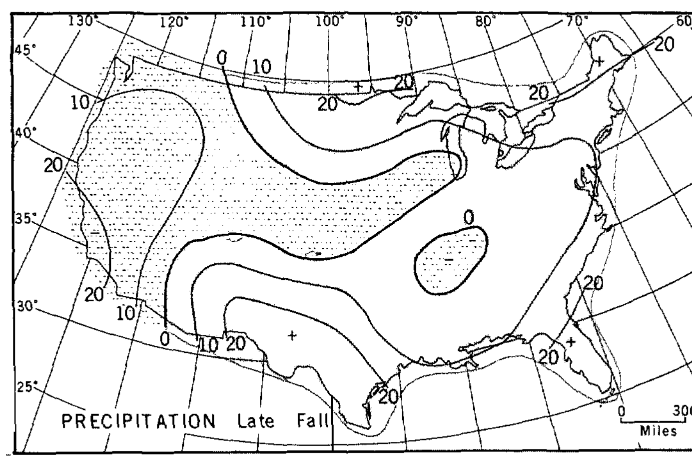

FIGURE 12.—Same as figure 7; late fall (November through December).

fact indicate a significant change in the climatic character of the United States with, broadly speaking, a warming of the eastern half from the middle of the last century to the time period of the current climatic normals and a minor cooling in the West, then they should fit in with other climatic changes in the last century which have been proposed by various investigators (Baerreis and Bryson 1965; Pedelaborde 1967; Lamb 1966; Lamb and Johnson 1959; Mitchell 1961, 1963). Lamb and Johnson (1959) have spearheaded such investigations; it is most encouraging to find that our results corroborate their findings which are chiefly concerned with the Atlantic-European sector of the Northern Hemisphere. Especially pertinent are their results related to the intensity and position of the surface trough over the Western Atlantic, this being a "feature of great prominence" in the early 1800's mean sea level pressure maps, and of typically "large amplitude in the Little Ice Age" (Lamb and Johnson 1959, page 119 and fig. 1). In figure 9 of their paper, they show the longitude of the trough position (at 45° N.) for 40-yr running averages from the early 1800's to the mid-20th century. A steady eastward motion is noticeable from the early 1800's until approximately the 40-yr period 1845–1884. During these years, the mean longitude decreased from around 56° W. to between 49° and 45° W.

Similar longitudinal changes also are found for the ridge west of the British Isles and the next trough downstream over western Europe. Thus, in the 40-yr period encompassing our period between 1830 and 1869, the trough off the east coast was still at about 51° W., 3° to 5° closer to the coast than during the first half of the 20th century (the farthest easterly position is found in the 40-yr period 1910–1949 at 45° W.). The obvious consequence of this change in pattern would be an increased average flow of polar air into the eastern half of the United States behind this trough in the mid-19th century. Furthermore, Lamb and Johnson (1959) noted that the maximum of mean sea level pressure over North America (at 45° N.) "appears nearly constant from decade to decade since the 1850's in 100°–105° W. This pressure maximum is situated under the confluent region upstream of the great trough in the upper westerlies and hence about half a wavelength west

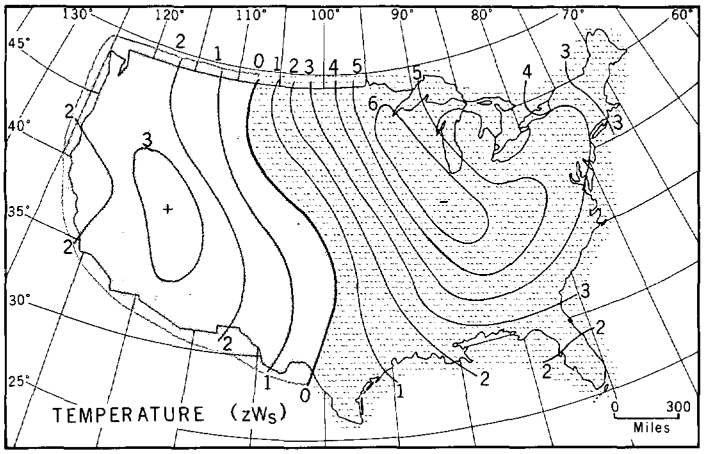

FIGURE 13.—Average departures from normal over the United States for months with extended occurrence of weather type zW_s over Europe; temperature pattern (°F). Winter months.

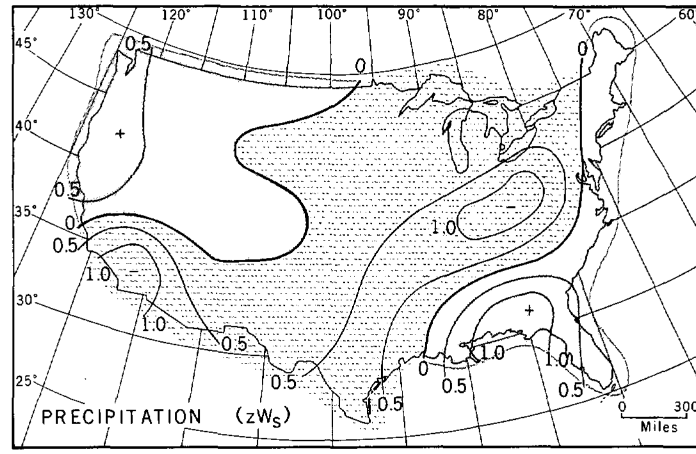

FIGURE 14.—Same as figure 13; precipitation pattern (percent of normal).

of the west Atlantic surface trough. The part of the pattern in the upper westerlies near 100°–105° W. is assumed to be nearly constant in position owing to the control exerted by the Rocky Mountains." This fact would point to an increase in the wavelength of the stationary long-wave pattern which, in turn, can be related to an increase of the upper level westerlies. While it may not be possible to use the simple formula relating mean westerly wind speed to wavelength of stationary waves, as was pointed out by Charney and Eliassen (1949), these authors, nevertheless, also show that the ridge over the West Coast (at about 120° W. at 500 mb) appears to be related to the topography of this region and could be reconstructed quite well by introducing frictional effects. In fact, they conclude that "the stationary perturbations in the westerlies are forced perturbations created by the forced ascent of the westerly current over the continents and modified by friction."

Detailed theoretical studies by Smagorinsky (1953) and Saltzman (1961, 1962), among others, have subsequently pointed out that in addition to the frictional effects, one also has to take into account thermal (diabatic) effects and the geographically fixed mean convergence field of heat and momentum due to transient eddies. This obviously complicates matters considerably, since changes in the westerlies (for example, Lamb's zonal index variations) will have direct feedback relations to these diabatic and eddy terms—due to the interrelations between zonal and eddy potential and kinetic energy conversions.

This relationship of our results to the large-scale circulation pattern change documented by Lamb and Johnson (1959) leads to another possibility, namely, the understanding of some teleconnections between rather far, distant regions. The decidedly smaller values of the zonal flow index (also established by Lamb and Johnson 1959, page 120) in the early 19th century together with the westerly displacement of the trough/ridge patterns has certain effects on both the European and American climatic behavior; thus, certain interrelated changes should occur in a definitive manner. One aspect of the relationship has been recently identified by Kornasiewicz (1969). Using the catalog of "Grosswetterlagen" (GWL) established by Hess and Brezowsky (1952), he investigated the temperature anomalies occurring over the United States for winter months with predominant occurrences of two such GWL's over Europe, both of which are indicative of generally westerly (zonal) flow. One of these is the GWL identified as zW—a "westerly zonal flow" occurring frequently over western Europe. Months with a high predominance of this type show a temperature departure pattern from normal with a warmer eastern and slightly cooler western half of the United States, that is about the opposite of our findings (or, in other words, the correct deviation for the years with high zonal flow in the early 1900's).

The other large-scale weather type, designated zW_s, "westerly zonal flow, occurring farther south than usual," usually has a rather low frequency of occurrence in the German catalog (encompassing the years 1881–current). When the months during which this zW_s-type was decidedly more prevalent than usual were averaged, the corresponding temperature and precipitation departures showed a rather striking similarity to our 1830's to 1860's patterns, as can be seen in figures 13 and 14. The postulated larger amplitude and westward displacement of the ridge/trough pattern in the 19th century would favor a somewhat higher frequency of this pattern over Europe; thus, the teleconnection between the occurrence frequency of zW_s-types over Europe and the simultaneous temperature/precipitation pattern over the United States becomes understandable and, even more important, indicative of the overall circulation change in the last 100 yr over at least half of the Northern Hemisphere.

5. FINAL REMARKS, THE 1960's

In the conclusions of the previous paper (Wahl 1968), it was suggested that "one has to consider not the 1830's and

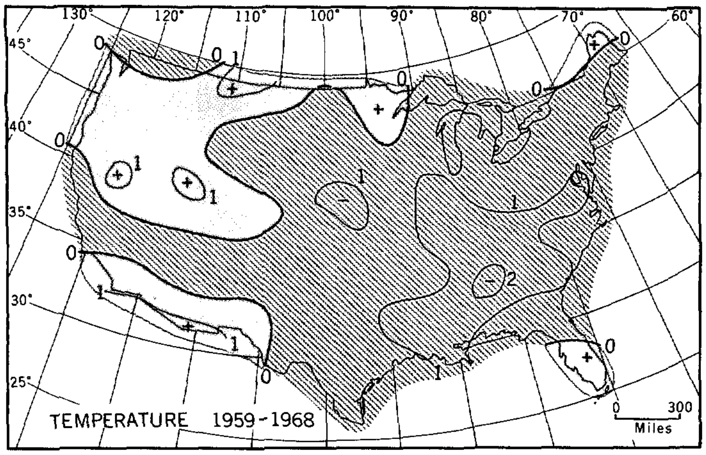

FIGURE 15.—Temperature deviations of data for the decade 1959–1968 from climatic normals 1931–1960; annual average (°F).

1840's as the abnormal decades, but may have to assume that the recent years constitute a temporary departure from the more 'normal' behavior at those times." One of the reasons for this conclusion was the absence of such rather large temperature departure patterns, even for a single year, during the current normal 30-yr period, 1931–1960; the only similar pattern with values approaching the mean pattern of the 1830's was found in 1966 (early fall). Our extension of the investigation to the next 20 yr (1850–1869) and to the whole United States now shows a pattern consistent both with the earlier result and with other evidence based on consideration of the changes in the large-scale circulation. From the latter, Lamb (1966) had already suggested that it appears likely that we have passed the height of the warming episode in the first half of this century and are now reverting to a pattern characterized by lower zonal flow and intensification of the trough/ridge systems, essentially a reestablishment of the climatic character of the last century.

We have attempted to verify this in a general way for the United States by deriving the "departure from normal" pattern (for temperature, on an annual basis) for the most recent 10 yr available, namely 1959–1968. In figure 15, this pattern based on selected first-order stations is shown. After considering the fact that this is based on only 10 yr (hardly a sufficient length of record for climatic averages) and in some cases most likely on stations which should not have been used in this way (we made no specific efforts to select the stations carefully with respect to exposure, station history, etc.), the general coincidence of this pattern with that given in figure 1 for the annual departures in the 1850's and 1860's is rather remarkable. In fact, this comparison says that it probably would be more reasonable to compare our most recent climatic data with the "normals" valid for the middle of the last century rather than with the 1931–1960 averages; or one might express this in an even more general way by asserting that we really are still in the "Little Ice Age" which was interrupted only briefly for something like 70 yr by a temporary warm spell in the Northern Hemisphere.

It has been suggested by various authors (Blodget 1857; Callendar 1958; Kaplan 1960; Mitchell 1968; Pales 1965; Plass 1956, 1957) that this warming trend over the Northern Hemisphere described in detail, for example, by Mitchell (1961, 1963) was caused by an increase in atmospheric CO_2 connected with the increasing use of fossil fuels by mankind. The apparent reversal of this increasing trend, on the other hand, has been attributed to an increase of particulate matter (dust) in the atmosphere, either from volcanic activity or manmade effects (Bryson and Wendland 1968; Humphreys 1913, 1920; Junge 1963; Mitchell 1968; Peterson and Bryson 1968). Our results, which essentially suggest a recent return to prewarming patterns over an admittedly very small part of the Northern Hemisphere, do not contradict either of these hypotheses; they also, however, could be interpreted as indicating a reestablishment of the general character of the climatic patterns typical of the larger climatic episode which has governed our climate for the last three to four centuries and which was interrupted only briefly by a minor climatic fluctuation.

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